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Solar Cells Performance Reduction under the Effect of Dust in Jazan Region

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Abstract

The accumulation of dust on the solar cells panels worsens the situation and lowers the efficiency of the solar cells day by day especially in the regions known by their high rate of dust, low frequency and intensity of rain. The accumulated dust on the solar cells panel blocks the cells from the sun's rays and act as a screening effect as shown by the calculated spectral transmittance of dust which decreases the performance of the solar cells over time until the cell panels are cleaned manually or by rain. The tilt angle of the solar cell panels affects considerably the amount of accumulated dust on the surface of the panels.

The study focuses on the effects of dust accumulation on photovoltaic solar panels in Jazan region. The effect is tested in outdoor measurements and it was found that regular dust accumulation reduces the solar cells efficiency by about 10% for an exposure time of 16 weeks. Moreover the tilted panel with an angle of 30° receives more dust than the panel tilted by 50° which means higher efficiency loss for the lower tilted panel. The efficiency loss is significant of large of annual monetary losses. This study can be considered as a reference to predict the level of degradation of any photovoltaic system that might be installed in the Jazan region and also to estimate the real cost include the cost of the solar panel cleaning.

Keywords: Solar cells; Dust accumulation; Efficiency; Transmittance

Introduction

With the increased demand on energy resources, energy prices will likely continue rising for the next decade. In addition the combustion of fossil fuels has led to a dramatic climate change. The world's leaders are actually conscious of this major problem and that it's time to implement other alternative technologies for obtaining safe and efficient energy. One option is the use of renewable resources energy especially solar energy that becomes a promising business, holding more than $24 billion market value [1]. This sustainable energy resource can help to solve worldwide energy insecurity. Despite the growing importance of electrical energy production by solar cells, the cost of solar power cells must be significantly reduced and their efficiency improved before they can successfully replace the current use of fossil fuels.

Currently, Scientists and engineers are working very hard to make solar electricity affordable on a large scale, long been trying to develop a low-cost solar cell, which is both highly efficient and easy to manufacture with high throughput. The drawback of solar cells can generate power when the exposure to the sun rays is enough. When the weather is cloudy or during sand or snow storms the power generation falls off or nearly stops. It can only provide power at night if excess is stored in batteries.

The performance of the solar energy system is related to the ability of the glass cover to allow radiation to penetrate through the collection surface. Many factors determine its effectiveness including the density of solar radiation at that area, the tilt angle of the panels, the properties of the materials, and the gradual degradation of collectors resulting from accumulation of dust [2] due to the shadowing effect.

Over the last decade, only few local studies have been done in the impact of dust on the degradation of the solar cells efficiency. However it is a serious problem that contributes to reduction of the solar cells efficiency by 40% [3]. In the last decade few studies analyzed this effect and the consequent efficiency degradation because the deposition of dust on solar cell panels is a complex phenomenon that is influenced by different environmental and weather conditions.

According to Hottel and Woertz paper published in 1940 [4] the performance of three sets of solar thermal flat-plate collectors were reduced by 1% in collector performance attributed to dust/dirt accumulating on a glass plate inclined at an angle of 30° from horizontal in an industrial area in United States of America.

In 1979 Studies by Nimmo and Seid [5] indicated a more degradation ranging from 26% to 40% in efficiency of thermal panels and photovoltaic cells respectively over 6 months. This study was somehow questionable because it gives misleading results. Later on in 1988, Salim et al. reported in their work a reduction of 32% of the solar cells performance after 8 months of dust accumulation on the solar panels in Riyadh region [6]. This effect was proved mathematically that the sand dust deposition on solar cell panels reduce the transmittance of light beam up to 50% [7]. This means a reduction on the power efficiency of the solar cells system. Recently, Kymakis et al. [8] attributed the solar cells power loss of 4-5% during the winter and 6-7% in summer to the type of dust deposited, the time lasts after the rainfall and the cleaning schedule. Moreover the experimental study conducted by Hassan et al. [9] indicated that the degradation of the solar cell performance decreased rapidly during the first 30 days of

exposure. Others studies investigating the impact of dust accumulation on solar cell panels comes out with results that confirmed the reduction of the electrical performance of solar cells system.

In this work we focus to find how the solar cell efficiency is affected by the settling dust in Jazan region for various lengths of exposure. This will help to predict how the performance of a the solar cell panels will be affected from degradation which will lead to identify technologies that will help prevent or better solve the problem in a more time- and cost-effective way.

Dust and Light Absorbance

The main cause of the reduction of solar cells power is the attenuation in transmittance of light due to the dust accumulation on the glass cover. The dust accumulation process is very easy it starts first by a simple layer accumulation until it covers all the surface, then a second layer will deposit on top of it and so on [2,7].

To calculate the scattered light efficiency, we suppose that the dust particles are spherical and are composed mainly by SiO_2, thus the refractive index for the Silicon oxide as function of the wavelength was used. When these particles are illuminated they will absorb and scatter the light, which will reduce the intensity of the light beam, this effect is known as the extinction efficiency that is governed by the ration of the particle size to the wavelength of the incident light [10].

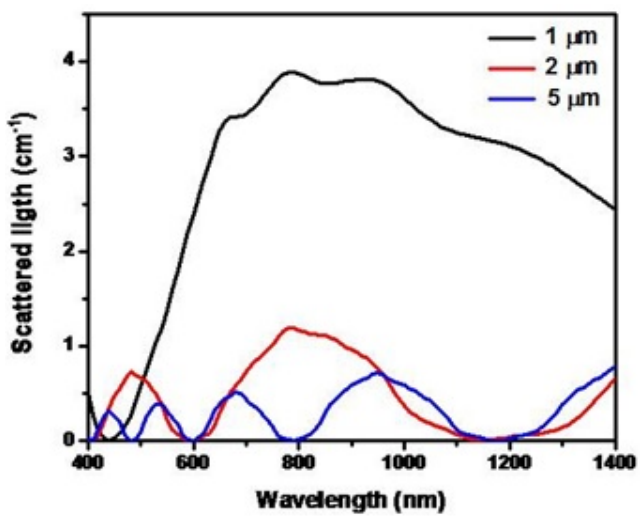

Figure 1: Computed scattered light obtained for dust particles 1, 2 and 5 µm at wavelength from 400-1400 nm using Mie Scatter model.

The particle extinction efficiency can be obtained by combining the effects of scattering and absorption. The Mie theory can serve as the basis of a computational procedure for calculating the scattering and absorption of light as a function of the wavelength [11,12].

The calculation results of the light attenuation are shown in the Figure 1 for different particle sizes ranging from 1 up to 5 µm diameter. We observe that particles with lower size (1 µm) scatter more light in the visible range of the solar spectrum than particles with high size. This effect was reported in previous work [13] in which they show that larger particles lead to more output due to the dependence of small particles to the light wavelength. Just to mention that we did not take into account the internal scattering between particles due to the computational limitation.

Dust Characterization

Desert dust in Jazan region represents a large fraction of the naturally particles composed mainly of feldspars, Gypsum, chert, and mica with a dominate compound of quartz [14].

These particles having diameters up to several microns and, therefore, they are able to scatter and absorb both the solar and terrestrial radiation affecting the solar cells efficiency. The analysis of a sample of dusts from a solar cells panel using an Olympus CX21I microscope and the Image J analyzer software gave more information on the grain size distribution. Figure 2A shows various particle size and shapes. Moreover the same image shows overlapped particles which add difficulty to the analysis of particles. The particles size distribution was found to be a Gaussian function centered at around 10 µm (Figure 2B), however, larger particles in the order of few tens µm diameter are also observed.

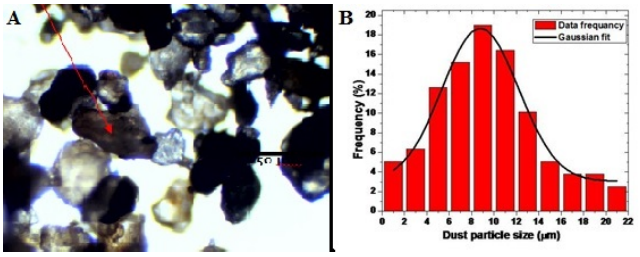

Figure 2: A. Dust grains, picture taken with microscope with 20X amplification; **B.** Frequency of dust particles during normal days.

Experiment Apparatus and Setup

The electrical study of the effect dust accumulation on the solar cells efficiency is conducted by using the two commercial 30W solar panel mounted on the roof of Science College at Jazan University. The latitude and longitude of the location are +16.9 (16°54'00"N) and +42.55 (42°33'00"E) and the temperature fluctuates are in the range of 22 to 38°C during the year in Jazan with an average humidity of 70% and wind speed of 15 km/h.

The electrical specifications of the panels used in this study were as follows:

- Peak Power (Pmax): 30 W
- Voltage (Vmp): 17.6 V
- Current (Imp): 1.704 A
- Open Circuit Voltage (Voc): 21.6 V
- Short Circuit Current (Isc): 1.9 A
- The size of the panel used was 540 mm × 450 mm × 28 mm.

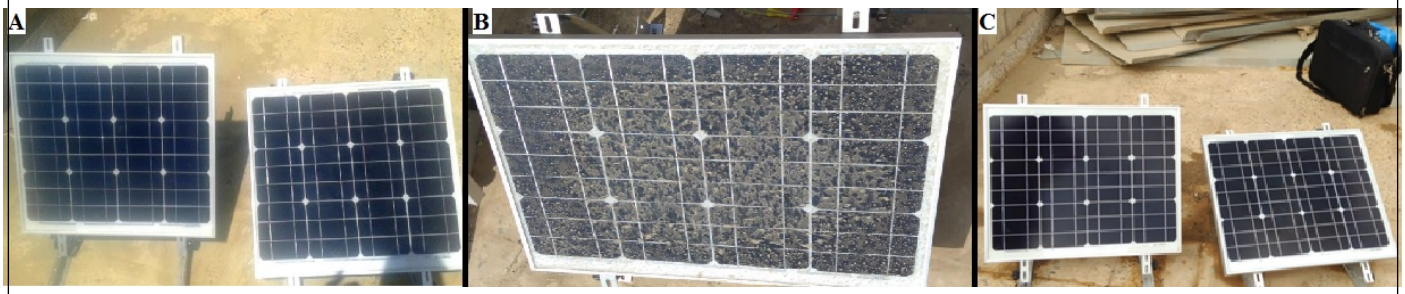

Figure 3: A. Solar cells state at the beginning of measurement; **B.** After a weak rainfall; **C.** After cleaning by smooth normal water.

Figure 3A shows the panels in the first day of the measurement and Figure 3B shows the state of the panels after a weak rainfall we can see clearly that the panel becomes dirty. To remove dirt from the surface of the solar cell panel was washed with normal water followed by a smooth fine to remove remaining water droplets which make the surface very clean as shown in the Figure 3C.

The following methodology was performed for the solar cells electrical output measurements by using the data from a portable IV Checker (MP-11) from EKO Company. The IV Checker that provides an IV curve, efficiency, voltage, current, and a maximum power point curve. The measurements were taken around 11:30 am, each Monday except where are cloudy or raining, so the data collection was delayed until the days with clear weather.

The solar irradiance was measured automatically by an external pyranometer that was placed on the solar cells glass. The solar irradiance data were automatically transferred to the IV checker to be used for the solar cells efficiency calculation.

The panels were cleaned with water in the beginning to remove small particles to allow a thorough reading. Also the operation of cleaning is repeated every time the panels become very dirty (after a light rain or a dust storm).

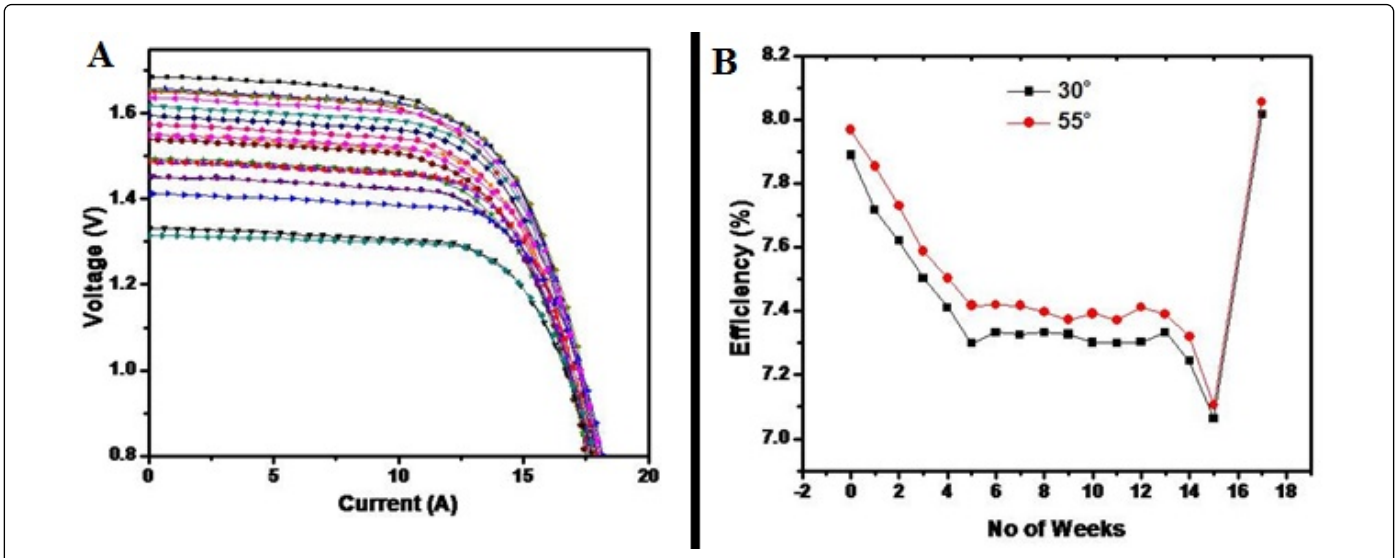

Figure 4: A. I-V characteristics for the solar cell panel measured for 16 weeks tilted; **B.** The corresponding efficiency for the two solar cells panel tilted at 30° and 55°.

Figure 4A shows the current-voltage or I-V curves for solar PV panels taken for every week for a period of 16 weeks. We can see clearly that the accumulation of dust during 16 weeks reduces the short-circuit current (Isc) and maximum current (Imax) for the IV characteristic whereas the open-circuit voltage (Voc) shows small variation. Moreover a little rain in the 14th week worsens the situation and reduces more the efficiency of the solar cells as we can see from image of the panel itself. For more details we plotted the efficiency for both solar cell panels for the 16 weeks, the results is shown in the Figure 4B. We can see clearly that for both tilt we have the same trend that's mean that the efficiency decreases with the accumulated dust on the surface of the panels and this reduction is more pronounced for the lower tilt which is an indication for accumulated dust. The efficiency curve can be divided in four parts:

First part starts from week zero till to 5th week in this portion we can see a linear reduction of the efficiency versus the time and the reduction of six percent in efficiency was observed in the fifth week.

The second part from 5th week to 13th week the efficiency is almost steady which an indication that in this period no or less dust was settled in the surface of the panels. After the 13th week a little rain was fallen in the region so, then surface of the panels becomes more dirty

than before the rain which worsen the situation and make the efficiency drops to the lower value for both tilt and this can be seen clearly from the pictures taken after the rainy day. The fourth part of the curve is marked by an increase in the efficiency even more than the initial values taken in the beginning because both solar cell panels were cleaned by water to remove all dirt. The net reduction of the solar cells efficiency due to the accumulation of dust in Jazan region is calculated from the Figure 4B and is around 10.4% for the panel tilted at 30° and 9.7% for the panel tilted at 55° which indicate that less dust accumulates on the panel tiled with higher angle due the gravity force that remove naturally some quantity of dust.

Figure 4A shows I-V characteristics for the solar cell panel measured for 16 weeks tilted and Figure 4B shows the corresponding efficiency for the two solar cells panel tilted at 30° and 55°.

Conclusion

The deposition and accumulation of airborne dust significantly reduce the output performance of the solar cells. In this work, real environment experiments were conducted in Jazan region to study the impact of dust deposition accumulation on commercial solar cells at different tilts.

The experimental results show that the deposition and accumulation of airborne dust on solar cell panels caused a significant reduction of the short circuit current consecutively during 15 weeks for both tilts leading to a reduction of the efficiency of the solar cells. This effect is due to the reduction in transmittance that is greatly affected by dust deposition density and particle sizes affected itself by the exposure duration and the inclination angle. Almost 10.4% of efficiency is lost for a period of 16 weeks for the panels tilted at 30° and 9.7% for the panels tilted at 55° which is considerably high considering the short exposure time to the dust. Moreover the weak rainfall worsens the situation and a cleaning with natural water is necessary to remove all dust and therefore better solar cells efficiency is obtained. But this operation is a time wasting if we consider large field of solar cell panels. For such case it is strongly recommended to use a self-cleaning system especially in dusty areas (such as Jazan region) that may be helpful to prevent dust accumulation and to enhance the module power performance.

Further and complete research is essential for more accurate results by using more panels, a longer time of exposure and on-site monitoring/recording the weather data including (temperature, wind speed, wind direction and humidity). Furthermore, we suggest that more efforts to be concentrated on the methods of surface treatment that potentially capable to reduce the adhesion force and to increase the removal efficiency of smaller particles and allow benefiting from the abundant sunlight and large vacant land in Jazan region.

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